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RESONANCE STUDIES OF HYDROGEN ATOMS INTERACTING WITH  
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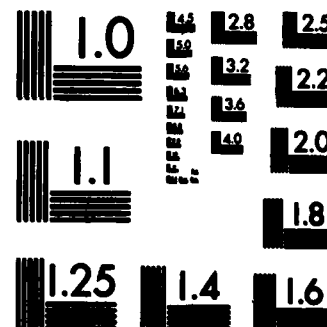
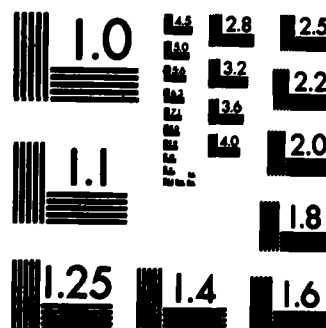
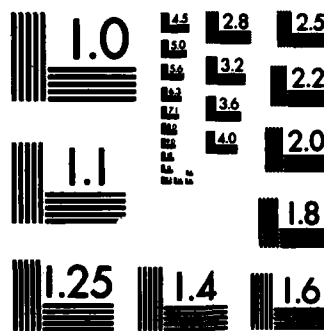
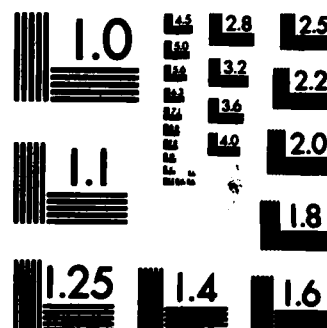
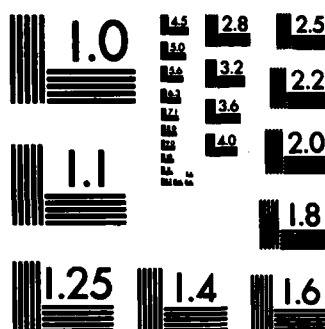
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ANNUAL SUMMARY REPORT

ONR Contract # N00014-80-C-0240

RESONANCE STUDIES OF HYDROGEN ATOMS INTERACTING WITH VERY COLD SURFACES

March 1, 1982 - February 28, 1983

The President and Trustees  
of Williams College  
Williamstown, Massachusetts  
01267

Stuart B. Crampton  
Department of Physics  
and Astronomy

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Techniques and information developed during previous studies of the ground state hyperfine resonance of hydrogen atoms intermittently adsorbed on molecular hydrogen surfaces are applied to the development of a state-selected low temperature hydrogen beam. Beam intensities up to $5 \times 10^{13} \text{ sec}^{-1}$ of $F=1$ , $M_F=0$ atoms are achieved and used to study hydrogen atom interactions near 4.2 K. Modifications for extending the temperature range are designed and made.		

## ANNUAL SUMMARY REPORT

ONR Contract # N00014-80-C-0240

### ATOMIC HYDROGEN MASER INVESTIGATIONS OF HYDROGEN ATOM INTERACTIONS FROM 4 K to 12 K

1. Principal Investigator: Dr. Stuart Crampton  
Williams College  
Williamstown, MA 01267

2. Contract Description:

A liquid helium temperature state-selected hydrogen atom beam is developed and incorporated into an atomic hydrogen maser operating with liquid helium temperature surfaces of molecular hydrogen and atomic neon. The likely performance of an atomic hydrogen maser operating at liquid helium temperatures as a primary or secondary frequency standard is investigated.

3. Scientific Problem

Recent experimental work originally motivated by the prospects for observing the Bose-Einstein condensation in a very low temperature gas of spin polarized atomic hydrogen have demonstrated that the density of hydrogen atoms that can be stored in low magnetic fields in containers coated with frozen inert gases is high enough and that the relaxation times while stored are long enough to offer attractive opportunities for precision measurements and for frequency metrology. The electron exchange collision relaxations and frequency shifts at very low temperatures offer sensitive tests of the fundamental interactions between colliding hydrogen atoms. Operation at very low temperatures offers potentially significant improvements of both short term and long term hydrogen maser stability.

4. Scientific and Technical Approach

Hydrogen atoms produced from molecules in a 180 MHz discharge cooled by liquid nitrogen are cooled to temperatures ranging from 4,2 K to 6 K in a copper tube cooled by liquid helium and then focused into a 5 cm diameter storage bottle by a conventional hexapole permanent magnet adapted for low atom speeds. A short pulse of

microwave radiation resonant at the hydrogen atom ground state  $F=1$ ,  $m_F=0$  to  $F=0$ ,  $m_F=0$  hyperfine transition sets the atoms radiating at frequencies and with lifetimes indicative of their interactions with the inert frozen surfaces inside the bottle and with each other while adsorbed on the surfaces. The amplitude of radiation is sensitive to the density of atoms in the storage bottle and the rate of relaxation of level populations, which can be independently measured.

At temperatures that are high enough that adsorption is relatively weak, it is not necessary to supply pulses of stimulating radiation, as the atoms are able to sustain a self-excited oscillation on the ground state hyperfine transition, as in a conventional room temperature atomic hydrogen maser. For a particular choice of storage surface, the temperature should be high enough that the adsorption is weak but low enough that collisions by the hydrogen atoms with the saturated vapor over the surface molecules do not introduce frequency perturbations and difficulties with the motional averaging of DC and RF magnetic fields. The relevant parameters for liquid helium surfaces below 1 K have been measured by Walter Hardy and his colleagues at the University of British Columbia in Vancouver. Because neon has less polarizability compared to its mass than helium, neon surfaces near 10 K may provide better hydrogen atom storage than liquid helium surfaces near 0.5 K. In addition, the exchange collision relaxation and frequency shift cross sections are appreciably smaller at 10 K than at 0.5 K.

## 5. Progress

The state-selected atomic hydrogen beam has been built and operated successfully with fluxes up to  $5 \times 10^{13} \text{ sec}^{-1}$  of atoms in the  $F=1$ ,  $m_F=0$  state. Straightforward improvements which should improve that by a factor of ten are in progress. The beam has been used to investigate the low density collision-free level population relaxation rates and to investigate neon surfaces near 4.2 K (where there is a problem of contamination by condensed molecular hydrogen). Equipment for varying the storage surface temperature upwards to 12 K has been designed and built.



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#### 6. Publications

Recent publications citing ONR support of this work include:

(a) S. B. Crampton, J. J. Krupczak and S. P. Souza, "Progress of the State-Selected Bea, Low Temperature Hydrogen Maser," Journal de Physique (Paris), Colloque C8-181 (1981)

(b) S. B. Crampton, J. J. Krupczak and S. P. Souza, "Temperature Dependence of Hydrogen-Atom Adsorption on Molecular-Hydrogen Surfaces," Physical Review B25, 4383 (1982).

#### 7. Extenuating Circumstances

Although the work has not proceeded as quickly as it would have but for things that had to be discovered and learned, the work has proceeded at a reasonable rate of successful development of new ideas and techniques.

#### 8. Unspent Funds

We have already spent or have committed to be spent by the end of February, 1983, over 90% of the funds available until then, and we do not anticipate any surplus.

#### 9. Graduate Student Degrass

There is no graduate program in physics at Williams College. Undergraduates who have participated in this research during the period of support by ONR have gone on to graduate study at the University of Wisconsin, the University of Maryland, and the University of Massachusetts at Amherst.

#### 10. Other Federal Grant and Contract Support

NSF Grant PHY82-05886 currently provides \$30,000 per year of parallel support for this work.



Stuart B. Crampton  
Principal Investigator

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